Exhibit A

UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF CALIFORNIA
SAN FRANCISCO DIVISION

BROADCOM CORPORATION and AVAGO TECHNOLOGIES INTERNATIONAL SALES PTE. LTD., *Plaintiffs*, v. NETFLIX, INC., *Defendant*.	Case No. 3:20-cv-04677-JD **DECLARATION OF MICHAEL T. GOODRICH, PH.D.**

I, Michael T. Goodrich, declare under penalty of perjury as follows:

Introduction and Summary

1. I have been asked to analyze U.S. Patent Nos. 7,457,722 (the '722 Patent); 8,548,976 (the '976 Patent); and 8,572,138 (the '138 Patent), and to provide an assessment as to the purpose of the claimed inventions, the problems claimed to be overcome by the claimed inventions, to what the claimed inventions are directed, as well as how the claimed inventions purportedly solve the problems laid out by the inventors.

2. I have also been asked to review Netflix's Motion for Judgment on the Pleadings (ECF No. 287), as it relates to my tasks identified in the above paragraph.

3. In summary, my opinions are as follows:

- The claims I reviewed of the three patents are all directed to improvements in specific technological processes.
- Each of these inventions is rooted in computer technology and provides specific solutions to problems that arise in computer technology.
- Netflix's assessment of the inventions is, on the whole, overly simplistic and apparently misunderstands or misconstrues the purpose of the claimed inventions.

4. I discuss all of this in greater detail below.

My Background and Qualifications

5. The following is a brief summary of my background and qualifications. My background and qualifications are more fully set out in my curriculum vitae (CV), which is included as Appendix A.

6. I am a Distinguished Professor in the Department of Computer Science at University of California, Irvine ("UCI"), where my responsibilities include teaching, performing research in Computer Science, mentoring undergraduate and graduate students, and serving on university committees. The Distinguished Professor title is a campus-level distinction at UCI that is reserved for above-scale faculty who have achieved the highest levels of scholarship over the course of their careers. Distinguished Professors will typically have earned national and

international level distinctions and honors of the highest level. Prior to my faculty position at UCI, I was a member of the faculty in the Department of Computer Science at Johns Hopkins University from 1987 to 2001, where my responsibilities also included teaching, performing research in Computer Science, mentoring undergraduate and graduate students, and serving on university committees.

7. I have over 35 years of experience in computer science, including the topics of algorithm design, data structures, networking, mobile devices, computer security, caching and mass storage optimization, and parallel and distributed computing. For example, I was a coprincipal investigator ("co-PI") on a $1.6M grant awarded in 1997 from the National Science Foundation on a networked computing environment for the manipulation and visualization of geometric data, I was co-PI on a $500K grant awarded in 2008 from the Office of Naval Research on scalable methods for the analysis of network-based data, and I was PI on a $500K grant awarded in 2010 from the National Science Foundation on trustworthy interactions in cloud computing. In addition, publications dealing with networking and/or caching and mass storage optimization include (using the numbering used in my CV) journal articles J-26, J-38, J-56, J-61, J-62, J-78, J-83, and peer-reviewed conference publications C-33, C-41, C-49, C-101, C-105, C-126, C-133, C-138, C-151, C-156, C-172, C-176, C-181, and C-187. For instance, in my journal article J-56, my coauthors and I study methods for partitioning data into push and pull regions so as to optimize communication costs between a server and several clients. In my capacity as a Distinguished Professor at University of California, Irvine, my responsibilities include teaching undergraduate and graduate students, performing research in computer science, mentoring PhD students and postdoctoral fellows, and serving on various university committees. I have been a professor at the University of California, Irvine since 2001. I have also served as an associate dean in the School of Information and Computer Sciences and as department chair for the Department of Computer Science.

8. I obtained a PhD in Computer Sciences from Purdue University in 1987. I also obtained a B.A. in Mathematics and Computer Science from Calvin College in 1983.

9. I have taught undergraduate and graduate courses concerning algorithms, data structures, software design, networking, and computer security, beginning with my work as a graduate student at Purdue in 1983 and continuing as a professor at Johns Hopkins and University of California, Irvine. In addition, I have taught courses on algorithms and Internet technologies during sabbaticals at the University of Illinois and Brown University, respectively. I supervise a research team that has, over the years, comprised 24 PhD students and 9 postdoctoral fellows. My current focus of our research includes work on networking, computer security, algorithm design, caching and mass storage optimization, data structures, and parallel and distributed computing.

10. As shown in my CV, I have authored or coauthored over 300 peer-reviewed publications, and I have served as an editor and peer reviewer for scholarly publications and journals, including refereed conference proceedings on the topics of networking, computer security, and algorithms. I have also published several books concerning algorithms, data structures, and computer security, including Algorithm Design and Applications, published by Wiley, and Introduction to Computer Security, published by Pearson. Some of these books have been translated into Chinese, Greek, Portuguese, and Spanish.

11. I am a Fellow of several industry and professional organizations, including Association for Computing Machinery (ACM), Institute of Electrical and Electronics Engineers (IEEE), and American Association for the Advancement of Science (AAAS). I also regularly attend and present at computer science conferences concerning algorithms, networking, and computer security, including SIAM Symposium on Discrete Algorithms (SODA), ACM Symposium on Computer and Communications Security (CCS), and ACM Symposium on Parallelism in Algorithms and Architectures (SPAA).

12. I have received several awards and recognitions for my work concerning algorithms and distributed computing, including a Dean's Award for Research in the School of Information and Computer Sciences at University of California, Irvine ("for contributions in the area of parallel and distributed algorithms"), a Robert B. Pond Sr. Award for Excellence in Undergraduate

Teaching from Johns Hopkins University, an IEEE Computer Society Technical Achievement Award ("for outstanding contributions to the design of parallel and distributed algorithms for fundamental combinatorial and geometric problems"), and a Chancellor's Award for Excellence in Fostering Undergraduate Research from Univ. of California, Irvine. In addition, I have been elected as a foreign member of the Royal Danish Academy of Sciences and Letters.

13. I am an inventor on four U.S. patents, including US 7,257,711, "Efficient Authenticated Dictionaries with Skip Lists and Commutative Hashing," which discloses methods for authenticating information that is distributed from centralized servers through third-party information distributors, US 7,299,219, "High Refresh-Rate Retrieval of Freshly Published Content using Distributed Crawling," which discloses a system for retrieving highly refreshed information quickly from Internet sources, US 8,681,145, "Attribute Transfer Between Computer Models Including Identifying Isomorphic Regions in Polygonal Meshes," which discloses technology for finding matchings between different geometric models, and US 9,152,716, "Techniques for Verifying Search Results Over a Distributed Collection," which discloses a technology for verifying information that is extracted by web crawling processes on the Internet.

<u>My Opinions Related to US Patent No. 7,457,722</u> (claims 1, 3, 4)

14. The '722 Patent claims are directed to a technological improvement related to performance monitoring of applications, application groups, and application tiers in distributed systems. This focus is clear throughout the '722 Patent and explicitly taught in the claims, including claims 1, 3, and 4, which I understand are the claims Plaintiffs are asserting against Netflix in this lawsuit. In short, the innovation here is related to a specific advancement in computer technology.

15. In reviewing the '722 Patent, the patent explains the explicit problem facing the inventors. The '722 Patent notes that "one of the biggest challenges is meeting the increasingly demanding service levels required by users" because "more applications directly accessible to customers . . . are now 24 hours a day, 7 days a week" and the "importance of monitoring and

maintaining the quality of computational services has increased dramatically.[1] As it relates to this litigation, anyone familiar with Netflix knows that it is important that Netflix monitors the quality of its service 24 hours a day and 7 days a week. The ’722 Patent is directed to such services, where various application instances executing as a part of the service experience “life-cycle” events, including application instance creation, application instance destruction, and application instance migration.[2]

16. Technologically speaking, however, this can be difficult. For example, in distributed computing environments, certain application instances may be created or destroyed as demand changes. These instances may also migrate from node to node in response to either a hardware or a software failure, or in response to load-balancing.[3] Further, in a distributed computing environment, there are often many different application instances running at any given time and multiple ways in which application instances can be created, destroyed, and/or migrated.

17. This creates a problem with respect to monitoring the performance of an application or application group/tier that would require keeping track of which particular application instances are currently running, which have completed their tasks successfully and terminated voluntarily, which have been destroyed due to a fault or being terminated involuntarily, and which have migrated from one computing platform to another. Indeed, this problem is specifically identified by the ’722 Patent:

> However, monitoring systems may be unable to track the migration of instances from node to node, thereby preventing the monitoring system from presenting a complete picture of a given application instance. Furthermore, monitoring systems may not be operable to monitor data on the creation or destruction of application instances. Existing prior art software performance monitors do not correlate performance data with events, such as the creation, migration or destruction of a particular application instance, and across all instances of a particular application, application group, and/or technology tier.[4]

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[1] ’722 Patent at 1:12-20.

[2] See, e.g, the ’722 Patent at Figs. 7 and 8, and at 7:14-8:15 and 8:16-9:16.

[3] ’722 Patent at 1:35-39.

[4] ’722 Patent at 1:39-49.

18. The problem, as explained above by the inventors, is that the prior systems were unable to provide a complete picture of the applications in a distributed system and were further unable to correlate performance data for an application or application group with the performance of specific application instances as application instances are created, destroyed, or migrated. Therefore, the monitoring solutions prior to the ’722 Patent were inferior.

19. The ’722 Patent, however, provides a solution to the problem. The ’722 Patent discloses “a system and method for performance monitoring including instance life cycle event monitoring” that includes creation, migration, and destruction monitoring.[5] The ’722 Patent also discloses how to correlate the creation, destruction, and/or migration of one or more specific application instances to provide a more complete assessment of an application, application group, or technology tier.[6] Thus, as opposed to the solutions prior to the ’722 Patent, the ’722 Patent is able to provide more thorough and useful monitoring, as is required now that applications are run – and run heavily –using high volumes of application instances that are constantly being created, destroyed, or migrated across ever-shifting compute resources within a distributed environment. By having consistent high-quality monitoring, applications and the servers that support them can run smoothly to process the requests of customers, but, as the ’722 Patent highlights, providing for all this monitoring using prior-art systems would create significant overheads.[7]

20. The solution is discussed throughout the ’722 Patent and recited in the claims, specifically claims 1, 3, and 4. For example, claim 1 specifically recites the technological solution described above (emphases added):

Claim 1: A method, comprising:

> collecting **performance data for one or more application instances**, wherein the **performance data is associated with the performance of said one or more**

[5] ’722 Patent at 1:53-65.

[6] *See e.g.*, ’722 Patent at 1:65-2:30 (“correlating said performance data to one or more instance life cycle events may comprise correlating the one or more instance life cycle events to the performance of the application . . .”).

[7] See, e.g., ’722 Patent at 1:21-34.

application instances, wherein each application instance is a computer program executing on a computer system;

detecting one or more instance life cycle events associated with said one or more application instances, wherein said one or more instance life cycle events comprise at least one of: the **creation** of at least one of said one or more application instances, the **destruction** of at least one of said one or more application instances, and the **migration** of at least one of said application instances;

correlating said performance data to said one or more instance life cycle events; and

storing the correlated performance data.

21. Claims 3 and 4 expressly relate to more specific events, including claim 3 related to application instances being created and destroyed and claim 4 relating to one or more application instances migrating from one location to another. This is recited below (emphases added):

Claim 3: The method of claim 2, wherein said **correlating said performance data** to one or more instance life cycle events comprises determining the change in performance of the application **as the one or more application instances are created and destroyed**.

Claim 4: The method of claim 2, wherein said **correlating said performance data** to one or more instance life cycle events comprises determining the change in performance of the application **as the one or more application instances migrate from one location to another location**.

22. These claims recite specific steps and functions to implement the technological advancement taught in the patent specification. For example, these claims provide the benefit of solving the problem identified in the patent, as I explain above, and are supported, for instance, at Figs. 7 and 8, and at 7:14-8:15 and 8:16-9:16.

23. I have reviewed Netflix's Motion for Judgment on the Pleadings (ECF No. 287, the "Netflix Motion") as it relates to the '722 Patent. Here, Netflix ignores the purpose of the invention and somehow associates "application instances" with an elementary student's tending her plants for a science project. This analogy is completely different than what is recited in claims 1, 3, and 4 of the '722 Patent. For example, this analogy does not account for the '722 Patent claims which recite a performance monitoring system that may be used to see different perspectives on how life cycle events affect specific application instances, applications, and application tiers.[8] Simply put, the claims of the '722 Patent are directed to a particular problem

[8] *See, e.g.*, '722 Patent at 8:65-9:6.

that arises in distributed computing systems and is not comparable to measuring the growth of a group of potted plants. The ’722 Patent clearly states that the field of its invention is “computer processing and, more particularly, to the monitoring of application performance.”[9]

24. Netflix ignores – or apparently misunderstands – the purpose of the patent, as I’ve discussed it above. This is a very specific solution to an application-monitoring issue in the realm of computer applications. Nothing in the claims discussed above is directed to simply monitoring and writing down what is monitored, as Netflix seems to argue. In fact, the ’722 Patent identifies that there are several other, though less successful, application monitoring solutions. The inventions disclosed in the ’722 Patent, however, overcome the problems associated with those lesser solutions. Associating this application-based monitoring solution with monitoring the growth of a plant is oversimplifying the claimed invention to an absurd degree. It is misunderstanding – or ignoring – the entire point and purpose of the invention, which is directed to a very specific problem that arises in the operation of applications in a distributed computing environment where compute resources and application instances are ever-changing. It is clear that the ’722 Patent’s advancement is related to monitoring and correlating application-instance life-cycle events and how to best do this in light of the problems described in the patent, as I discuss above.

25. In short, the ’722 Patent and in particular claims 1, 3, and 4 are directed to specific technological solutions that are rooted in computer technology, and these solutions are claimed specifically to overcome the problems the ’722 Patent identifies which, again, and as I describe above, are problems in the realm of computer technology, specifically application monitoring and the correlation of application instance life cycle events.

26. Further, in my opinion, claims 1, 3, and 4 disclose improvements to computer functionality itself. For example, as I explain above and as recognized in the specification, prior-art monitoring systems may be unable to track the migration of instances from node to node, thereby preventing the monitoring system from presenting a complete picture of a given

[9] ’722 Patent at 1:8-10.

application instance. Furthermore, prior-art monitoring systems may not be operable to monitor data on the creation or destruction of application instances. Also, prior art software performance monitors do not correlate performance data with events, such as the creation, migration or destruction of a particular application instance, and across all instances of a particular application, application group, and/or technology tier.[10] In contrast, claims 1, 3, and 4 solve these problems, providing improvements to computer functionality itself, including improvements for distributed system monitoring and management, so as to collect life cycle events and correlate performance data with those events. This allows a distributed computer system to better manage its computational resources, including CPU usage and memory usage, as well as keeping track of how well the system is functioning with respect to life-cycle events.

27. In addition, in my opinion, the elements of claims 1, 3, and 4 are combined so as to claim an inventive concept. For example, claims 1, 3, and 4 recite a specific combination of steps that, on my experience in the field, was not routine and conventional as of the priority date of the ’722 Patent. For instance, combining the detection of life cycle events and the correlation of such events with performance data for one or more application instances solves the problem identified by the ’722 Patent regarding the inability of prior art systems to monitor life cycle events of application instances and correlate them to provide a complete picture of the performance of an application or application group. .

28. Further, I disagree with Netflix’s apparent argument that a person of ordinary skill would be unable to practice claims 1, 3, and 4 in light of the specification, because of a supposed lack of disclosure of algorithms for performing the claimed methods. As even Netflix acknowledges, the ’722 Patent provides flow charts, e.g., in Figs. 7 and 8, for algorithms for performing its claimed methods, and it further describes additional details for these algorithms in prose at 7:14-8:15 and 8:16-9:16, respectively. In my opinion, these disclosures are more than sufficient to inform a person of ordinary skill as to how to implement the claimed methods in program instructions and these disclosures support claims 1, 3, and 4.

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[10] *See, e.g.,* ’722 Patent at 1:39-49.

<u>My Opinions Related to US Patent No. 8,548,976</u> (claims 9, 22)

29. The ’976 Patent claims are directed to a technological improvement related to connecting to web services whereby a web server is selected independent of input from a requested application in order to provide greater operational control over the provisioning of web services and improved load balancing and failover capabilities. The focus of the inventions is clear throughout the ’976 Patent, from the patent specification to the claims, and starting already with the patent title. For example, in the Description of the Related Art, the ’976 Patent specifically discusses the challenges businesses face in providing web services:

> Because of the very large number of potential web service users and the complexity of many web services, web services can push even the most capable servers running the web services to their limits. Web service use is often referred to as load. Servers that run web services generally have a load capacity indicating the quantity of load the server can handle. Servers that may be over loaded may not be able to function properly. For example, an over loaded server may stop handling requests for web services. An overloaded server may also cease functioning, thereby denying all web service requests.[11]

30. As the ’976 Patent describes with regard to the related art, before a software system can utilize a web service, the requesting application must first locate and connect to a server providing that web service.[12] Moreover, to prevent any particular server from being pushed to its limits, the requesting application should locate a server for a web service that is available and has sufficient current load capacity to perform the requested service. For example, a system (not practicing the ’976 Patent) might direct a requesting application to a server that has become non-functional due to it becoming overloaded with requests, such as a server performing a web service for an online ticket distribution system that then becomes overloaded with ticket purchase requests from users hoping to buy tickets to a concert. Such an overload could occur, for instance, because requests are being directed to a primary server without the ability to detect when the primary server becomes non-functional and failover to a secondary server. For

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[11] ’976 Patent at 1:60-2:3.

[12] ’976 Patent at 1:34-38.

example, the ’976 Patent explains existing options “for handling the problem of excess load,” but also explains the drawbacks of these options:

> One option for handling the problem of excess load is to use more powerful servers to run the web services. More powerful servers may be able to handle more simultaneous requests for web services and/or web services requiring more rigorous computation. This potential solution is limited. For example, the great number of users of a web service may overload even the most powerful servers. Additionally, more powerful servers may be disproportionably more expensive. For example, a server that is marginally more powerful may be substantially more expensive.[13]

31. The ’976 Patent, overcoming the drawbacks of other options for handling the issue identified, presents a system and method for claimed solutions directed to the problem described without any requirement for input from the requesting application subsequent to the selection of a web service. For example, in the Summary, the ’976 Patent identifies the distinct “web service-selecting unit” and “server-selecting unit” components that may be used in the inventive method and computer system to connect to a web service without input from a requesting application:

> A system for connecting to a web service including a web service-selecting unit for selecting a web service, a server-selecting unit for selecting a server among one or more servers capable of running the selected web service, a determining unit for determining a real address for the selected web service running on the selected server, and a connecting unit for connecting to the selected web service running on the selected server using the determined real address.[14]

32. The ’976 Patent goes far beyond this and teaches, particularly as it relates to the asserted claims 9 and 22, the importance of “**awareness**.” For example, if there is an awareness that “the web service server is properly functioning, the proxy 102 may establish a connection with the web service on the primary server using the determined real address on the requesting application's 101 behalf (Step S509).”[15] The steps to accomplish this are explained in detail. For example, the ’976 Patent teaches the following:

> The proxy 102 may be made aware of the current state of the server on which the web service is primarily run (the primary server) (Step S506). This primary server may either be functional (Yes Step S506) or non-functional (No Step S506). To accomplish this, the proxy 102 may, for example, attempt to establish a connection with the server running the web service. For example, the proxy 102 may access a

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[13] ’976 Patent at 2:4-14.

[14] ’976 Patent at 3:11-18; *see also* ’976 Patent at 3-10, 19-28.

[15] ’976 Patent at 7:15-20.

> web service status service (either on the same server or on a different server) that indicates whether the primary web service server may be functioning correctly. Alternatively, the proxy 102 may be made aware of the status of a web service server by receiving feedback from a previous requesting application 101. Alternatively, the server may be given the capability of notifying the proxy 102 in the event that the server may not be properly functioning.[16]

As the '976 Patent explains, by implementing the claimed inventions, a business may retain greater operational control and visibility over the load balancing and failover techniques used to provide its web services to users.

> In this way, the requesting application 101 need not be made aware that it is accessing a replacement server and the business maintaining the servers may thereby prevent users from knowing about server failures.[17]

33. The solutions outlined above, and taught throughout the '976 Patent, are recited in the '976 Patent claims. Asserted claim 9 depends upon claim 1. Claim 1 specifically recites the technological solution I describe above. This is explicit:

> Claim 1: A method for connecting to a web service, the method comprising:
>
> selecting a web service;
>
> selecting a server among one or more servers capable of running the selected web service,
>
> the selected server being selected independent of input from a requesting application subsequent to selection of the web service;
>
> determining a real address for the selected web service running on the selected server; and
>
> connecting to the selected web service running on the selected server using the determined real address.

34. The "awareness" solution I also discuss above is recited in both asserted claims 9 and 22 (emphases added):

> Claim 9: The method of claim 1, wherein selecting a server among one or more servers capable of running the selected web service comprises:
>
> **becoming aware of the status of a primary server** of the one or more servers capable of running the selected web service;
>
> selecting the primary server when the primary **server has a status of functional**;
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> and selecting a secondary server of the one or more servers capable of running the selected web service **when the primary server has a status of non-functional**.

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[16] '976 Patent at 6:58-7:5; *see also* '976 Patent at 7:65-15.

[17] '976 Patent at 7:36-39.

Claim 22: The computer system of claim 14, wherein the code for selecting a server among one or more servers capable of running the selected web service comprises:

code for becoming aware of the status of a primary server of the one or more servers capable of running the selected web service;

code for selecting the primary server **when the primary server has a status of functional**; and

code for selecting a secondary server of the one or more servers capable of running the selected web service **when the primary server has a status of non-functional**.

35. These claims recite specific steps and functions to implement the technological advancement taught in the patent specification.[18]

36. I have reviewed the Netflix Motion as it relates to the ’976 Patent. Netflix argues that claim 1 is directed to “the abstract idea of using an index to retrieve information.” My opinion on this point is that Netflix misunderstands the ’976 Patent. Nothing in the claims discussed above is directed to simply retrieving information using an index. This is oversimplifying the claimed invention. In fact, it is apparently misunderstanding or ignoring the entire point and purpose of the invention of claims 9 and 22, as I explain above.

37. It is clear that the ’976 Patent’s advancement is directed to a specific technological improvement for connecting to a web service and how to best do this in light of the problems described in the patent, as I discussed above. Importantly, the Netflix Motion fails to discuss, or even mention, the “awareness” solution that I discuss above. This solution is discussed at length in the ’976 Patent and is incorporated into the specific asserted claims, which I also discuss above.

38. Instead, the ’976 Patent, in claims 9 and 22, is directed to specific technological solutions that are rooted in computer technology, and these solutions are claimed specifically to overcome the problems the ’976 Patent identifies which, again, are problems in the realm of computer technology, as I explain above.

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[18] *See, e.g.,* ’976 Patent at Figs. 3, 4, 5, and 6, and at 4:46-6:10, 6:11-37, 6:38-7:50, and 7:51-8:25.

39. Further, in my opinion, claims 9 and 22 disclose improvements to computer functionality itself. For example, as I explain above, and as disclosed in the '976 Patent at 2:4-14, the '976 Patent discloses a solution to the "awareness" problem that allows a system to avoid excess load on servers providing a web service without having to resort to larger, more expensive hardware. For example, by being able to become aware of the status of a primary server, selecting that server when it is functional, and failing over to a secondary server with the primary server is non-functional, the claimed invention allows a smaller, less expensive system to do the work that would otherwise be required for a larger, more expensive system.[19] In addition, by being able to select a server to provide the selected web service without any input from the requesting application subsequent to the selection of the web service, the claimed invention allows a business to prevent users from knowing about server failures.

40. Further, in my opinion, the elements of claims 9 and 22 are combined so as to claim an inventive concept. For example, the '976 Patent claims an inventive concept that combines "selecting a web service," "selecting a server among one or more servers capable of running the selected web service," "determining a real address for the selected web service running on the selected server," and "connecting to the selected web service running on the selected server using the determined real address" in a solution to the "awareness" problem that combines these elements with those of "becoming aware of the status of a primary server of the one or more servers capable of running the selected web service," "selecting the primary server when the primary server has a status of functional," and "selecting a secondary server of the one or more servers capable of running the selected web service when the primary server has a status of non-functional." Netflix's citation to the Background section misunderstands the claimed invention. Further, I do not find Netflix's citation to the Background section regarding server failover at 2:54-56 ("A failover may be a redundant or standby server that can automatically take over for the primary server in the event the primary server fails.") as disclosing acknowledged prior art, especially when combined with the elements of claim 1, given that the passage continues by

[19] '976 Patent at 2:4-14.

disclosing benefits for elements of claims 9 and 22 (which unlike the prior art are combined with the elements of claim 1 in the ’976 Patent):

> A failover may be a redundant or standby server that can automatically take over for the primary server in the event the primary server fails. Failover servers may be referred to as “hot standby” or “warm standby” servers. The use of a failover allows for the web service to continue handling requests even in the event of a server malfunction, for example, the failover server (secondary server) may take over for the primary server when excess load causes the primary server to fail. However, the usefulness of the failover server is not limited to handling problems associated with excess load. Failovers may be used to ensure the continued offering of web services in any number of circumstances that may render the primary server non-functional.[20]

41. Moreover, contrary to Netflix’s apparent argument, the ’976 Patent does not disclose the use of generic computers or conventional technologies. Indeed, the ’976 Patent does not contain the words “generic,” “routine,” or “conventional” at all. For example, rather than disclose generic computers, the ’976 Patent claims “servers capable of running the selected web service,” that is, specific servers capable of providing a specific web service.

42. Further, I disagree with Netflix’s apparent argument that a person of ordinary skill would be unable to practice claims 9 and 22 in light of the specification, because of a supposed lack of disclosure of algorithms for “how” to implement the claimed invention. For example, the ’976 Patent provides flow charts, e.g., in Figs. 3, 4, 5, and 6, for algorithms for performing its claimed methods, and it further describes additional details for these algorithms in prose at 4:46-6:10, 6:11-37, 6:38-7:50, and 7:51-8:25, respectively. In my opinion, these disclosures are more than sufficient to inform a person of ordinary skill as to how to implement the claimed methods.

<u>My Opinions Related to US Patent No. 8,572,138</u> (claims 1, 11, 14)

43. The ’138 Patent claims are directed to a specific technological improvement related to a distributed computing system that conforms to a multi-level, hierarchical organizational model, and the ’138 Patent makes clear the problem that the inventors are attempting to solve. For instance, in the Background of the ’138 Patent, it is explained that “distributed computing systems are constructed from a collection of computing notes that combine to provide a set of

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[20] ’976 Patent at 2:54-67.

processing services to implement the distributed computing applications," but there is a challenge:

> One challenge with distributed computing systems is the organization, deployment and administration of such a system within an enterprise environment. For example, it is often difficult to manage the allocation and deployment of enterprise computing functions within the distributed computing system. An enterprise, for example, often includes several business groups, and each group may have competing and variable computing requirements.[21]

44. The '138 Patent discloses solutions to this issue facing computer systems, one of which is the use of emulating a computer platform, i.e., utilizing a virtual machine. For example, the '138 Patent teaches:

> When deployed on physical node 200, virtual machine manager 402 hosts virtual machines 404A through 404N (collectively, virtual machines 404). The term virtual machine is used herein to refer to software that creates an environment that emulates a computer platform. For example, virtual machines 40 provide environments on which guest operating systems (OS) execute as through the operating systems were operating directly on a physical computing platform. In this manner, multiple operating systems and software applications 406A through 406N (collectively, operating systems and applications 406) may execute on virtual machines 404A through 404N, respectively, and the virtual machines 404 may execute on a single physical node 400 or multiple physical nodes.[22]

45. The '138 Patent goes on to explain that this use of a virtual machine manager and virtual machines provides "a level of independence from the particular hardware environment provided by physical node 400."[23] Addressing the challenge discussed above, the '138 Patent continues to explain that:

> After generation of image instances for virtual machine manager 402 and virtual disk image files 408, control node 12 may deploy the image instance of virtual machine manager 402 to one or more nodes in free pool 13. Once control node 12 deploys the image instance of virtual machine manager 402 to a node, the node appears to be one or more new, unallocated nodes. For instance, if the image instance of virtual machine manager 402 is configured to support five virtual machines, control node 12 represents the newly deployed image instance as though five new, unallocated nodes have been added to free pool 13. Subsequently, control node 12 may deploy an image instance of virtual disk image files 408 to one of the new unallocated nodes.[24]

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[21] '138 Patent at 1:15-34.

[22] '138 Patent at 32:65-33:11.

[23] '138 Patent at 33:21-24.

[24] '138 Patent at 34:1-13.

46. The solutions discussed above, which are only a few examples which I pulled from the patent, are identified to specifically address the problems laid out in the ’138 Patent.

47. Like the patents discussed above, the solutions taught by the ’138 Patent are specifically included in the claims, including claims 1, 11, and 14, which I understand are the claims asserted by Plaintiffs in this litigation. Note that claims 11 and 14 depend upon claim 9, which depends upon claim 1. For this reason, I analyze claim 1 below, which clearly recites the solution described by the ’138 Patent. [Emphases added.]

> <u>Claim 1</u>: A distributed computing system comprising:
>
> a software image repository comprising non-transitory, computer-readable media operable to store:
>
> (i) a plurality of image instances of a virtual machine manager that is executable on a plurality of application nodes, wherein when executed on the applications nodes, **the image instances of the virtual machine manager provide a plurality of virtual machines, each of the plurality of virtual machine operable to provide an environment that emulates a computer platform**, and
>
> (ii) a plurality of image instances of a plurality of software applications that are **executable on the plurality of virtual machines**; and
>
> a control node that comprises an automation infrastructure to **provide autonomic deployment of the plurality of image instances of the virtual machine manager** on the application nodes by causing the plurality of image instances of the virtual machine manager to be copied from the software image repository to the application nodes and to **provide autonomic deployment of the plurality of image instances of the software applications on the virtual machines** by causing the plurality of image instances of the software applications to be copied from the software image repository to the application nodes.

48. Claim 1, along with clams 11 and 14, recites specific steps and functions to implement the technological advancement taught in the patent specification and as I discussed above in this section. For example, claim 1 recites the specific improvement in distributing software images, which are computer programs, through the use of virtual machines to application nodes. This is a specific improvement in computer functionality, as I explain below, since it provides a layered, hierarchical deployment architecture.

49. Claims 11 and 14 derive from claim 9, which recites:

> 9. The distributed computing system of claim 1, wherein the control node further comprises one or more rule engines that provide autonomic deployment of the software applications to the virtual machines in accordance with a set of one or more rules.

50. Thus, claim 9 adds the inventive concept of the limitations of claim 1 combined with using a rule engine that provides autonomic deployment of software applications to the virtual machines (of claim 1) in accordance with a set of one or more rules.

51. Claims 11 and 14 are as follows:

> 11. The distributed computing system of claim 9, wherein the automation infrastructure automatically updates the one or more rules engines to autonomically control the deployment of the Software applications to the application nodes in accordance with a current state of an application matrix.
>
> 14. The distributed computing system of claim 9, wherein the automation infrastructure automatically updates the one or more rules engines to monitor the execution of the software applications when deployed to the application nodes in accordance with a current state of the application matrix.

52. Thus, claims 11 and 14 combine the previous elements with the inventive concept of the application matrix.

53. I have reviewed the Netflix Motion as it relates to the ’138 Patent. Netflix argues that claim 1 is directed “automatically distributing software from a repository to computers.” But, like the patents above, Netflix apparently ignores or misunderstands the purpose of the invention. The ’138 Patent is not directed to merely distributing software. For example, the ’138 Patent states that the field of its invention is “computing environments and, more specifically, to distributed computing systems.”[25]

54. As Netflix notes, distributing software has been done. But because Netflix flattens the entire invention to a handful of words, completely removing the inventive purpose and ignoring the claim language, Netflix then argues that this is merely software distribution. This is wrong. For example, although Netflix acknowledges that the parties agree that an “image instance” is “a snapshot, or copy, of installed and configured software,”[26] Netflix apparently ignores the implications of this construction. For example, since an “image instance” is “a snapshot, or copy, of **installed** and **configured** software,” it is not merely generic copies of software that are being stored in a repository that are **then** distributed to be installed on various computers. Instead, the

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[25] ’138 Patent at 1:11-12.

[26] Citing to Dkt. No. 112 at 2.

image instances are **already** installed and configured snapshots or copies for (1) "a virtual machine manager that is executable on a plurality of application nodes, wherein when executed on the applications nodes, the image instances of the virtual machine manager provide a plurality of virtual machines, each of the plurality of virtual machine operable to provide an environment that emulates a computer platform," and (2) "a plurality of software applications that are executable on the plurality of virtual machines." I disagree with Netflix characterization that "[d]espite the long and seemingly complicated claim language, when stripped of its technical jargon, claim 1 has two components: (1) a software repository that stores master copies of three different types of prior-art software, and (2) a controller that automatically copies software from the repository to computers."

55. The so-called "technical jargon" here comprises claim limitations that Netflix glosses over in its reductive and incomplete analysis. For example, claim 1 recites a layered software architecture comprising image instances for a virtual machine manager and image instances for applications, such that there is a "control node" that provides autonomic deployment of **both** the instances for a virtual machine manager **and** applications. Moreover, rather than being generic software, each of the plurality of virtual machines is operable to provide an environment that emulates a computer platform. Further, Netflix's reductive argument ignores the "automation infrastructure" and the autonomic functionality of the control node of claim 1, as well as the layered deployment of image instances for both a virtual machine manager and also for applications. Thus, I disagree with Netflix's argument that Broadcom is wrong in identifying a "hierarchical organizational model" and an "infrastructure management facility" as inventive concepts present in the claims, as I find these inventive concepts, respectively, in the layered deployment of image instances for a virtual machine manager and applications, and in the combination of the "control node," "automation infrastructure," and "software image repository."[27]

[27] *See, e.g.,* '138 Patent at claims 1, 11, and 14.

56. As explained above, the inventions claimed in the ’138 Patent are directed to a specific solution to a particular problem in computer software. This particular solution, especially in the combination described in the patent specification and claimed, was a new solution that solved a significant problem, as I explain above.

57. Netflix makes arguments that certain components are known components but, again, this misses the point, while also using a slight-of-hand of asking the Court to ignore “technical jargon” to draw attention away from novel limitations in claims 1, 11, and 14. Of course, software applications are known generally, but it is specifically how applications and virtual machines are utilized that is inventive along with novel limitations not found in the prior art. Netflix completely disregards the problem discussed and the claimed solutions to said problem.

58. Like the other patents I discussed above, it is apparent that the ’138 Patent’s advancement is wholly addressing problems in the realm of computer technology. For example, in my opinion, image instances, virtual machines, applications, rule engines, and application matrices have no embodiments outside of computing.

59. Further, in my opinion, Netflix incorrectly conflates the “rules engine” limitation of claims 11 and 14 with generic rule engines from other unrelated cases. Further, Netflix ignores the “application matrix” limitations in their arguments. When combined with the other elements, the “rule engine” and “application matrix” limitations of claims 11 and 14 provide an additional specific technological improvement or inventive concept, as they can provide “a system that specifies data for controlling the deployment of a set of applications within a distributed computing system, and perform operations to provide autonomic control over the deployment of the applications within the distributed computing system in accordance with parameters of the application matrix.”[28] Further, in my opinion, these limitations disclose improvements to the functioning of computers themselves, e.g., because they support the autonomic control over the deployment of the applications, thereby allowing for parameterized deployments rather than generic one-size-fits-all deployments.

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[28] ’138 Patent at 2:8-14.

60. Thus, in my opinion, the '138 Patent claims are not merely running some abstract idea on a generic computer. Instead, the patent claims are *improving* the functionality of computer technology.

I declare under penalty of perjury that the foregoing is true and correct. Signed this 4th day of January, 2023, in the State of Hawaii.

Michael T. Goodrich

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Appendix A

CURRICULUM VITAE

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EDUCATION

Ph.D.	1987	*Efficient Parallel Techniques for Computational Geometry* Computer Science, Purdue Univ. (M.J. Atallah, advisor)
M.S.	1985	Computer Science, Purdue Univ.
B.A.	1983	Mathematics and Computer Science, Calvin Univ.

PROFESSIONAL EXPERIENCE

July '19 to present	Distinguished Professor, Dept. of Computer Science Univ. of California, Irvine
April '07 to June '19	Chancellor's Professor, Dept. of Computer Science Univ. of California, Irvine
July '12 to June '13	Chair, Dept. of Computer Science Univ. of California, Irvine
October '06 to June '12	Assoc. Dean for Faculty Dev., Bren School of Info. and Comp. Sci. Univ. of California, Irvine
July '01 to March '07	Professor, Dept. of Computer Science Univ. of California, Irvine
Fall '00	Visiting Professor of Computer Science Brown Univ.
July '96 to June '02	Professor of Computer Science (on leave, from July '01) Johns Hopkins Univ.
July '92 to June '96	Associate Professor of Computer Science Johns Hopkins Univ.
Spring '94	Visiting Associate Professor of Computer Science Univ. of Illinois, Urbana-Champaign
July '87 to June '92	Assistant Professor of Computer Science Johns Hopkins Univ.

RESEARCH INTERESTS

Algorithm and data structure design
Information assurance, privacy, and security
Principles of database, machine learning, and typesetting systems
Parallel and distributed computing
Information visualization, computer graphics, and computational geometry

PRIZES, HONORS, AND AWARDS

- *Compere Loveless Fellowship in Computer Sciences*, Purdue Univ., 1985
- *Research Initiation Award*, National Science Foundation, 1988
- *Oraculum Award for Excellence in Teaching*, Johns Hopkins, 1993, 1994, 1995
- *ACM Recognition of Service Award*, 1996
- *Robert B. Pond, Sr. Award for Excellence in Undergraduate Teaching*, Johns Hopkins, 1998
- *Elected Senior Member*, the Institute of Electrical and Electronics Engineers (IEEE), 1999

- *Spirit of Technology Transition Award*, DARPA Dynamic Coalitions Program, 2002
- *Brown Univ. Award for Technological Innovation* (with R. Tamassia, N. Triandopoulos, D. Yao, and D. Ellis), 2006
- *ACM Distinguished Scientist*, 2006
- *2006 IEEE Computer Society Technical Achievement Award*, “for outstanding contributions to the design of parallel and distributed algorithms for fundamental combinatorial and geometric problems”
- *Fulbright Scholar*, 2007, for senior specialist service to University of Aarhus, Denmark
- *Fellow of the San Diego Supercomputer Center*, 2007
- *Fellow of the American Association for the Advancement of Science (AAAS)*, “for distinguished contributions to parallel and distributed algorithms for combinatorial and geometric problems, and excellence in teaching, academic and professional service, and textbook writing,” 2007
- *Named as Chancellor’s Professor*, for “demonstrated unusual academic merit and whose continued promise for scholarly achievement is unusually high,” Univ. of California, Irvine, 2007
- *Fellow of the Institute of Electrical and Electronics Engineers (IEEE)*, “for contributions to parallel and distributed algorithms for combinatorial and geometric problems,” 2009
- *Fellow of the ACM*, “for contributions to data structures and algorithms for combinatorial and geometric problems,” 2009
- *ICS Dean’s Award for Research*, “for contributions in the area of parallel and distributed algorithms,” 2014
- *Chancellor’s Award for Excellence in Fostering Undergraduate Research*, Univ. of California, Irvine, 2016
- *Faculty Mentor of the Month*, Undergraduate Research Opportunities Program (UROP), Univ. of California, Irvine, April 2016
- *Elected as a foreign member*, Royal Danish Academy of Sciences and Letters, April 2018
- *Named as Distinguished Professor*, for achieving “the highest levels of scholarship” over the course of a career and having “earned national and international level distinctions and honors of the highest level,” Univ. of California, Irvine, 2019

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C-182. M.J. Bannister, W.E. Devanny, M.T. Goodrich, J.A. Simons, and Lowell Trott, "Windows into Geometric Events: Data Structures for Time-Windowed Querying of Temporal Point Sets," *26th Canadian Conf. on Computational Geometry* (CCCG), 2014.

C-183. M.J. Bannister, W.E. Devanny, D. Eppstein and M.T. Goodrich, "The Galois Complexity of Graph Drawing: Why Numerical Solutions are Ubiquitous for Force-Directed, Spectral, and Circle Packing Drawings," *22nd Int. Symp. Graph Drawing* (GD), Springer, LNCS, vol. 8871, 149–161, 2014. (Preliminary version of J-86.)

C-184. M.J. Alam, D. Eppstein, M.T. Goodrich, S. Kobourov and S. Pupyrev, "Balanced Circle Packings for Planar Graphs," *22nd Int. Symp. Graph Drawing* (GD), Springer, LNCS, vol. 8871, 125–136, 2014.

C-185. M. Bannister, M.T. Goodrich, and P. Sampson, "Force-Directed 3D Arc Diagrams," *22nd Int. Symp. Graph Drawing* (GD), Springer, LNCS, vol. 8871, 521–522, 2014.

C-186. M.T. Goodrich and P. Pszona, "Two-Phase Bicriterion Search for Finding Fast and Efficient Electric Vehicle Routes," *22nd ACM SIGSPATIAL Int. Conf. on Adv. Geographic Information Systems* (GIS), 193–202, 2014.

C-187. M.T. Goodrich and J. Simons, "Data-Oblivious Graph Algorithms in Outsourced External Memory," *8th Int. Conf. on Combinatorial Optimization and Applications* (COCOA), LNCS, Vol. 8881, 241–257, 2014.

C-188. M.T. Goodrich, T. Johnson, M. Torres, "Knuthian Drawings of Series-Parallel Flowcharts," *23rd Int. Symp. on Graph Drawing and Network Visualization* (GD), Springer, LNCS, vol. 9411, 556–557, 2015. (See also http://arxiv.org/abs/1508.03931.)

C-189. M.T. Goodrich and A. Eldawy, "Parallel Algorithms for Summing Floating-Point Numbers," *28th ACM Symp. on Parallel Algorithms and Architectures* (SPAA), 13–22, 2016.

C-190. W.E. Devanny, M.T. Goodrich, and K. Jetviroj, "Parallel Equivalence Class Sorting: Algorithms, Lower Bounds, and Distribution-Based Analysis," *28th ACM Symp. on Parallel Algorithms and Architectures* (SPAA), 265–274, 2016.

C-191. D. Eppstein, M.T. Goodrich, J. Lam, N. Mamano, M. Mitzenmacher, and M. Torres, "Models and Algorithms for Graph Watermarking," *19th Information Security Conf.* (ISC), 283–301, 2016. **Best Student Paper Award**.

C-192. E. Ghosh, M.T. Goodrich, O. Ohrimenko, R. Tamassia, "Verifiable Zero-Knowledge Order Queries and Updates for Fully Dynamic Lists and Trees," *10th Conf. on Security and Cryptography for Networks* (SCN), 216–236, 2016.

C-193. M.T. Goodrich, E. Kornaropoulos, M. Mitzenmacher, R. Tamassia, "More Practical and Secure History-Independent Hash Tables," *21st European Symp. on Research in Computer Security* (ESORICS), 20-38, 2016.

C-194. J.J. Besa Vial, W.E. Devanny, D. Eppstein, and M.T. Goodrich, "Scheduling Autonomous Vehicle Platoons Through an Unregulated Intersection," *2016 Workshop on Algorithmic Approaches for Transportation Modeling, Optimization, and Systems* (ATMOS), 5:1–5:14.

C-195. M.J. Alam, M.B. Dillencourt, and M.T. Goodrich, "Capturing Lombardi Flow in Orthogonal Drawings by Minimizing the Number of Segments," *24th Int. Symp. on Graph Drawing and Network Visualization* (GD), LNCS, Vol. 9801, 608–610, 2016.

C-196. M.J. Alam, M.T. Goodrich, and T. Johnson, "Sibling-First Recursive Graph Drawing for Java Bytecode," *24th Int. Symp. on Graph Drawing and Network Visualization* (GD), LNCS, Vol. 9801, 611–612, 2016.

C-197. M.T. Goodrich, S. Gupta, and M. Torres, "A Topological Algorithm for Determining How Road Networks Evolve Over Time," *24th ACM SIGSPATIAL Int. Conf. on Advances in Geographic Information Systems* (GIS), 31:1–31:10, 2016.

C-198. M.J. Alam, M.T. Goodrich, and T. Johnson, "J-Viz: Finding Algorithmic Complexity Attacks via Graph Visualization of Java Bytecode," *13th IEEE Symp. on Visualization for Cyber Security* (VizSec), 1–8, 2016.

C-199. M.T. Goodrich, E. Kornaropoulos, M. Mitzenmacher, and R. Tamassia, "Auditable Data Structures," *2nd IEEE European Symp. on Security and Privacy* (EuroS&P), 285–300, 2017.

C-200. D. Eppstein, M.T. Goodrich, M. Mitzenmacher, and M. Torres, "2-3 Cuckoo Filters for Faster Triangle Listing and Set Intersection," *36th ACM SIGMOD-SIGACT-SIGART Symposium on Principles of Database Systems* (PODS), 247–260, 2017.

C-201. D. Eppstein, M.T. Goodrich, and N. Mamano, "Algorithms for Stable Matching and Clustering in a Grid," *18th International Workshop on Combinatorial Image Analysis* (IWCIA), 117–131, 2017.

C-202. G. Ateniese, M.T. Goodrich, V. Lekakis, C. Papamanthou, E. Paraskevas, and R. Tamassia, "Accountable Storage," *15th International Conference on Applied Cryptography and Network Security* (ACNS), 623–644, 2017.

C-203. D. Eppstein and M.T. Goodrich, "Using Multi-Level Parallelism and 2-3 Cuckoo Filters for Faster Set Intersection Queries and Sparse Boolean Matrix Multiplication," *29th ACM Symp. on Parallelism in Algorithms and Architectures* (SPAA), 137–139, 2017.

C-204. W.E. Devanny, J. Fineman, M.T. Goodrich, and T. Kopelowitz, "The Online House Numbering Problem: Min-Max Online List Labeling," *25th European Symposium on Algorithms* (ESA), 33:1–33:15, 2017.

C-205. M.T. Goodrich, "Answering Spatial Multiple-Set Intersection Queries Using 2-3 Cuckoo Hash-Filters," *25th ACM SIGSPATIAL Int. Conf. on Advances in Geographic Information Systems* (GIS), 65:1–65:4, 2017.

C-206. D. Eppstein, M.T. Goodrich, D. Korkmaz, and N. Mamano, "Defining Equitable Geographic Districts in Road Networks via Stable Matching," *25th ACM SIGSPATIAL Int. Conf. on Advances in Geographic Information Systems* (GIS), 52:1–52:4, 2017.

C-207. M.T. Goodrich, "BIOS ORAM: Improved Privacy-Preserving Data Access for Parameterized Outsourced Storage,' *ACM Workshop on Privacy in the Electronic Society* (WPES), 41–50, 2017.

C-208. J.J. Besa Vial, W.E. Devanny, D. Eppstein, M.T. Goodrich, and T. Johnson, "Quadratic Time Algorithms Appear to be Optimal for Sorting Evolving Data," *Algorithm Engineering & Experiments* (ALENEX), 87–96, 2018.

C-209. D. Eppstein, M.T. Goodrich, N. Mamano, "Reactive Proximity Data Structures for Graphs," *13th Latin American Theoretical Informatics Symposium* (LATIN), LNCS, Vol. 10807, Springer, 777–789, 2018.

C-210. M.T. Goodrich, "Isogrammic-Fusion ORAM: Improved Statistically Secure Privacy-Preserving Cloud Data Access for Thin Clients," *13th ACM ASIA Conf. on Information, Computer and Communications Security* (ASIACCS), 699–706, 2018.

C-211. J.J. Besa Vial, W.E. Devanny, D. Eppstein, M.T. Goodrich, and T. Johnson, "Optimally Sorting Evolving Data," *45th Int. Colloq. on Automata, Languages, and Programming* (ICALP), 81:1–81:13, 2018.

C-212. G. Barequet, D. Eppstein, M.T. Goodrich, and N. Mamano, "Stable-Matching Voronoi Diagrams: Combinatorial Complexity and Algorithms," *45th Int. Colloq. on Automata,*

Languages, and Programming (ICALP), 89:1–89:14, 2018.

C-213. G. Da Lozzo, D. Eppstein, M.T. Goodrich, and S. Gupta, "Subexponential-Time and FPT Algorithms for Embedded Flat Clustered Planarity," *44th Int. Workshop on Graph-Theoretic Concepts in Computer Science* (WG), 111–124, 2018.

C-214. G. Barequet, M. De, and M.T. Goodrich, "Computing Convex-Straight-Skeleton Voronoi Diagrams for Segments and Convex Polygons," *24th International Computing and Combinatorics Conference* (COCOON), 130–142, 2018. (Preliminary version of J-90.)

C-215. M.T. Goodrich and T. Johnson, "Low Ply Drawings of Trees and 2-Trees," *30th Canadian Conference on Computational Geometry* (CCCG), 1–9, 2018.

C-216. D. Eppstein, M.T. Goodrich, J. Jorgensen, and M.R. Torres, "Geometric Fingerprint Recognition via Oriented Point-Set Pattern Matching," *30th Canadian Conference on Computational Geometry* (CCCG), 1–16, 2018.

C-217. G. Da Lozzo, D. Eppstein, M.T. Goodrich, and S. Gupta, "C-Planarity Testing of Embedded Clustered Graphs with Bounded Dual Carving-Width," *14th Int. Symp. on Parameterized and Exact Computation* (IPEC), LIPIcs, vol. 148, 9:1–9:17, 2019. **Best Paper Award**.

C-218. J.J. Besa, G. Da Lozzo, and M.T. Goodrich, "Computing k-Modal Embeddings of Planar Digraphs," *European Symposium on Algorithms* (ESA), 19:1–19:16, 2019.

C-219. N. Mamano, A. Efrat, D. Eppstein, D. Frishberg, M.T. Goodrich, S. Kobourov, P. Matias, and V. Polishchuk, "New Applications of Nearest-Neighbor Chains: Euclidean TSP and Motorcycle Graphs," *30th Int. Symp. on Algorithms and Computation* (ISAAC), 51:1–51:21, 2019.

C-220. D. Eppstein, M.T. Goodrich, J.A. Liu, and P.A. Matias, "Tracking Paths in Planar Graphs," *30th Int. Symp. on Algorithms and Computation* (ISAAC), 54:1–54:17, 2019.

C-221. J.J. Besa, M.T. Goodrich, T. Johnson, and M.C. Osegueda, "Minimum-Width Drawings of Phylogenetic Trees," *13th Int. Conf. on Combinatorial Optimization and Applications* (COCOA), LNCS, vol. 11949, 39–55, 2019.

C-222. M.T. Goodrich, Z.M. Liang, and S. Zhao, "Inverse-Rendering Based Analysis of the Fine Illumination Effects in the Salvator Mundi," *ACM SIGGRAPH Art Papers Program, 47th International Conference and Exhibition on Computer Graphics and Interactive Techniques*, 2020.

C-223. R. Afshar, M.T. Goodrich, P. Matias, and M.C. Osegueda, "Reconstructing Binary Trees in Parallel," *32nd ACM Symp. on Parallelism in Algorithms and Architectures* (SPAA), 491–492, 2020.

C-224. R. Afshar, M.T. Goodrich, P. Matias, and M.C. Osegueda, "Reconstructing Biological and Digital Phylogenetic Trees in Parallel," *European Symposium on Algorithms* (ESA), 3:1–3:24, 2020.

C-225. R. Afshar, A. Amir, M.T. Goodrich, and P. Matias, "Adaptive Exact Learning in a Mixed-Up World: Dealing with Periodicity, Errors, and Jumbled-Index Queries in String Reconstruction," *27th International Symposium on String Processing and Information Retrieval* (SPIRE), 155–174, 2020.

C-226. M.T. Goodrich, R. Jacob, N. Sitchinava, "Atomic Power in Forks: A Super-Logarithmic Lower Bound for Implementing Butterfly Networks in the Nonatomic Binary Fork-Join Model," *ACM-SIAM Symp. on Discrete Algorithms* (SODA), 2141–2153, 2021.

C-227. R. Afshar, M.T. Goodrich, P. Matias, and M.C. Osegueda, "Parallel Network Mapping Algorithms," *33rd ACM Symp. on Parallelism in Algorithms and Architectures* (SPAA), 410–413, 2021.

C-228. M.T. Goodrich, S. Gupta, H. Khodabandeh, and P. Matias, "How to Catch Marathon Cheaters: New Approximation Algorithms for Tracking Paths," *17th Algorithms and Data Structures Symposium* (WADS), 442–456, 2021.

C-229. R. Afshar, M.T. Goodrich, P. Matias, and M.C. Osegueda, "Mapping Networks via Parallel kth-Hop Traceroute Queries," *39th Int. Symp. on Theoretical Aspects of Computer Science* (STACS), LIPIcs, Vol. 219, 4:1–4:21, 2022.

C-230. R. Afshar, M.T. Goodrich, and E. Ozel, "Efficient Exact Learning Algorithms for Road Networks and Other Graphs with Bounded Clustering Degrees," *20th Int. Symp. on Experimental Algorithms* (SEA), 9:1–9:18, 2022.

C-231. G. Barequet, S. Fukuzawa, M.T. Goodrich, D. Mount, M. Osegueda, and E. Ozel, "Diamonds are Forever in the Blockchain: Geometric Polyhedral Point-Set Pattern Matching," *34th Canadian Conf. on Computational Geometry* (CCCG), 16–23, 2022.

C-232. R. Afshar and M.T. Goodrich, "Exact Learning of Multitrees and Almost-Trees Using Path Queries," *15th Latin American Theoretical Informatics Symposium* (LATIN), 293-311, 2022.

C-233. M.T. Goodrich and E. Ozel, "Modeling the Small-World Phenomenon with Road Networks," *30th ACM SIGSPATIAL Int. Conf. on Advances in Geographic Information Systems* (GIS), 46:1-46:10, 2022. **Best Paper Runner Up Award**.

Other Publications:

O-1. M.T. Goodrich, "Guest Editor's Introduction," *International Journal of Computational Geometry & Applications*, **2**(2), 1992, 113–116.

O-2. M.T. Goodrich, "Parallel Algorithms Column 1: Models of Computation," *SIGACT News*, **24**(4), 1993, 16–21.

O-3. M.T. Goodrich, V. Mirelli, M. Orletsky, and J. Salowe, "Decision tree construction in fixed dimensions: Being global is hard but local greed is good," Technical Report TR-95-1, Johns Hopkins University, Department of Computer Science, Baltimore, MD 21218, May 1995.

O-4. R. Tamassia, P.K. Agarwal, N. Amato, D.Z. Chen, D. Dobkin, R.L.S. Drysdale, S. Fortune, M.T. Goodrich, J. Hershberger, J. O'Rourke, F.P. Preparata, J.-R. Sack, S. Suri, I.G. Tollis, J.S. Vitter, and S. Whitesides, "Strategic Directions in Computational Geometry Working Group Report," *ACM Computing Surveys*, **28A**(4), December 1996.

O-5. G.A. Gibson, J.S. Vitter, and J. Wilkes, A. Choudhary, P. Corbett, T.H. Cormen, C.S. Ellis, M.T. Goodrich, P. Highnam, D. Kotz, K. Li, R. Muntz, J. Pasquale, M. Satyanarayanan, D.E. Vengroff, "Report of the Working Group on Storage I/O Issues in Large-Scale Computing," *ACM Computing Surveys*, **28A**(4), December 1996.

O-6. T.H. Cormen and M.T. Goodrich, "A Bridging Model for Parallel Computation, Communication, and I/O," *ACM Computing Surveys*, **28A**(4), December 1996.

O-7. M.T. Goodrich, "Computer Science Issues in the National Virtual Observatory," in *Virtual Observatories of the Future*, ASP Conf. Series, vol. 225, R.J. Brunner, S.G. Djorgovski, and A.S. Szalay, eds., 329–332, 2001.

O-8. M.T. Dickerson and M.T. Goodrich, "Matching Points to a Convex Polygonal Boundary," Proceedings of the 13th Canadian Conf. on Computational Geometry (CCCG'01), 89–92, 2001.

O-9. M.T. Goodrich, "Guest Editor's Foreword," *Algorithmica*, **33**(3), 271, 2002.

O-10. M.T. Goodrich, M. Shin, C.D. Straub, and R. Tamassia, "Distributed Data Authentication (System Demonstration)," *DARPA Information Survivability Conf. and Exposition*, IEEE Press, Volume 2, 58–59, 2003.

O-11. M.T. Goodrich and R. Tamassia, "Efficient and Scalable Infrastructure Support for Dynamic Coalitions," *DARPA Information Survivability Conf. and Exposition*, IEEE Press, Volume 2, 246–251, 2003.

O-12. E. Ghosh, M.T. Goodrich, O. Ohrimenko, and R. Tamassia, "Poster: Zero-Knowledge Authenticated Order Queries and Applications," *IEEE Symp. on Security and Privacy*, 2015. (See also https://eprint.iacr.org/2015/283.)

O-13. F. Bayatbabolghani, M. Blanton, M. Aliasgari, and M.T. Goodrich, "Poster: Secure Computations of Trigonometric and Inverse Trigonometric Functions," *IEEE Symposium on Security and Privacy*, 2017.

PROFESSIONAL SERVICE

Guest Editor:

Int. Journal of Computational Geometry & Applications, **2**(2), 1992
Journal of Computer & System Sciences, **52**(1), 1996
Computational Geometry: Theory and Applications, **12(1–2)**, 1999.
Algorithmica, **33**(3), 2002.

Editorial Board Membership:

Computational Geometry: Theory and Applications, 2006–2015
Journal of Computer & System Sciences, 1994–2011
Journal of Graph Algorithms and Applications, 1996–2011
Int. Journal of Computational Geometry & Applications, 1993–2010
Information Processing Letters, 1995–1997

Journal Advisory Board Membership:

Int. Journal of Computational Geometry & Applications, 2010–
Journal of Graph Algorithms and Applications, 2011–

Program Committee Service:

7th ACM Symp. on Computational Geometry (SoCG), 1991
1991 Workshop on Algorithms and Data Structures (WADS)
8th ACM Symp. on Computational Geometry (SoCG), 1992
25th ACM Symp. on Theory of Computing (STOC), 1993
Chair, 26th ACM Symp. on Theory of Computing (STOC), 1994
11th ACM Symp. on Computational Geometry (SoCG), 1995
DAGS '95 Conf. on Electronic Publishing and the Information Superhighway
1996 SIAM Discrete Mathematics Conference
1997 Workshop on Algorithms and Data Structures (WADS)
International Symp. on Graph Drawing (GD), 1997
1999 Workshop on Algorithms and Data Structures (WADS)
Co-chair, Workshop on Algorithm Engineering and Experimentation (ALENEX), 1999
International Symp. on Graph Drawing (GD), 2000
2000 Workshop on Algorithm Engineering (WAE)
41st IEEE Symp. on Foundations of Computer Science (FOCS), 2000
2001 Workshop on Algorithms and Data Structures (WADS)
International Symp. on Graph Drawing (GD), 2001
Workshop on Algorithm Engineering and Experimentation (ALENEX), 2002
18th ACM Symp. on Computational Geometry (SoCG), 2002
13th ACM-SIAM Symp. on Discrete Algorithms (SODA), 2002
Co-Chair, Graph Drawing 2002

International Symp. on Graph Drawing (GD), 2003
16th ACM-SIAM Symp. on Discrete Algorithms (SODA), 2005
32nd Int. Colloq. on Automata, Languages and Programming (ICALP), 2005
12th Int. Computing and Combinatorics Conference (COCOON), 2006
13th ACM Conf. on Computer and Communication Security (CCS), 2006
15th European Symp. on Algorithms (ESA), 2007
5th International Conference on Applied Cryptography and Network Security (ACNS), 2007
21st IEEE International Parallel & Distributed Processing Symp. (IPDPS), 2007
19th ACM Symp. on Parallelism in Algorithms and Architectures (SPAA), 2007
5th Workshop on Algorithms and Models for the Web-Graph (WAW), 2007
7th International Workshop on Experimental Algorithms (WEA), 2008
Second International Frontiers of Algorithmics Workshop (FAW), 2008
16th ACM SIGSPATIAL Int. Symp. on Adv. in Geographic Information Systems (GIS), 2008
17th ACM SIGSPATIAL Int. Symp. on Adv. in Geographic Information Systems (GIS), 2009
31st IEEE Symp. on Security and Privacy (S&P), 2010
18th Int. Symp. on Graph Drawing (GD), 2010
2011 Workshop on Analytic Algorithmics and Combinatorics (ANALCO)
8th Workshop on Algorithms and Models for the Web Graph (WAW), 2011
19th International Symp. on Graph Drawing (GD), 2011
24th ACM Symp. on Parallelism in Algorithms and Architectures (SPAA), 2012
20th European Symp. on Algorithms (ESA), 2012
2013 IEEE Int. Conf. on Big Data (BigData), 2013
30th IEEE Int. Conf. on Data Engineering (ICDE), 2014
21st ACM Conf. on Computer and Communication Security (CCS), 2014
Symp. on Algorithms and Data Structures (WADS), 2015
ACM Cloud Computing Security Workshop (CCSW), 2015
International Symp. on Graph Drawing (GD), 2015
co-chair, 2016 Workshop on Algorithm Engineering and Experiments (ALENEX)
2016 Workshop on Massive Data Algorithmics (MASSIVE)
2016 Int. Symp. on Algorithms and Computation (ISAAC)
29th ACM Symp. on Parallelism in Algorithms and Architectures (SPAA), 2017
25th ACM SIGSPATIAL Int. Conf. on Adv. in Geographic Information Systems (GIS), 2017
26th European Symp. on Algorithms (ESA), 2018
26th ACM SIGSPATIAL Int. Conf. on Adv. in Geographic Information Systems (GIS), 2018
2nd Symp. on Simplicity in Algorithms (SOSA), 2019
1st ACM SIGSPATIAL Int. Workshop on Spatial Gems, 2019
2021 SIAM Symp. on Applied Computational & Discrete Algorithms (ACDA)
2023 SIAM Symp. on Algorithm Engineering and Experimentation (ALENEX)
35th ACM Symp. on Parallelism in Algorithms and Architectures (SPAA), 2023

Conference/Workshop Committee Service:

Conference chair, 12th ACM Symposium on Computational Geometry, 1996
Organizer, 1st CGC Workshop on Computational Geometry, 1996
Co-chair, 1999 Dagstuhl Workshop on Computational Geometry, 1999
Conference chair, Graph Drawing, 2002
Co-organizer, Hawaiian Workshop on Parallel Algorithms, 2017, 2019

Steering Committee and Executive Committee Service:

Member at large, ACM SIG on Algorithms & Comp. Theory (SIGACT) Exec. Comm., 1993–97
Member, Exec. comm. for 1996 Federated Computing Research Conference (FCRC)
co-Founder and member, Steering Comm. for Workshop on Algorithm Engineering and Experimentation (ALENEX), 1999–2017 (chair, 2014–16)

co-Chair, Steering Comm. for ACM Symposium on Computational Geometry, 1999–2001
Member, Steering Comm. for Graph Drawing Conference, 2000–03, 2014–16
Conference Chair, ACM SIG on Algorithms & Comp. Theory (SIGACT), 2005–09

Center and Institute Affiliations:

Algorithms, Combinatorics and Optimization Center, UCI
Center for Algorithms and Theory of Computation, UCI
Center for Embedded and Cyber-physical Systems, UCI
Center for Machine Learning and Intelligent Systems, UCI
The Institute for Virtual Environments and Computer Games (IVECG), UCI
Secure Computing & Networking Center, UCI

Postdoctoral Fellows:

1. Timothy Chan, Johns Hopkins, 1996. (Now at Univ. of Illinois)
2. Gill Barequet, Johns Hopkins, 1996-98. (Now at Technion)
3. Pawel Gajer, Johns Hopkins, 2000. (Now at Univ. of Maryland)
4. Amitabh Chaudhary, UC-Irvine, 2002-2004. (Now at U. Chicago)
5. Amitabha Bagchi, UC-Irvine, 2002-2004. (Now at IIT-Dehli)
6. Martin Nollenburg, UC-Irvine, 2010, mentored jointly with David Eppstein. (Now at TU Wien)
7. Maarten Loffler, UC-Irvine, 2010-2011, mentored jointly with David Eppstein. (Now at Utrecht University)
8. Md. Jawaherul Alam, UC-Irvine, 2015-16. (Now at Amazon)
9. Giordano Da Lozzo, UC-Irvine, 2016-2017, mentored jointly with David Eppstein. (Now at "Roma Tre" University)

Ph.D. Students:

1. Mujtaba Ghouse, "Randomized Parallel Computational Geometry in Theory and Practice," Johns Hopkins Univ., May 1993.
2. Paul Tanenbaum, "On Geometric Representations of Partially Ordered Sets," Johns Hopkins Univ., May 1995 (co-advised with Edward Scheinerman).
3. Mark Orletsky, "Practical Methods for Geometric Searching Problems with Experimental Validation," Johns Hopkins Univ., May 1996.
4. Kumar Ramaiyer, "Geometric Data Structures and Applications," Johns Hopkins Univ., Aug. 1996.
5. Christian Duncan, "Balanced Aspect Ratio Trees," Johns Hopkins Univ., Aug. 1999.
6. Christopher Wagner, "Graph Visualization and Network Routing," Johns Hopkins Univ., Oct. 1999 (co-advised with Prof. Lenore Cowen).
7. Stephen Kobourov, "Algorithms for Drawing Large Graphs," Johns Hopkins Univ., May 2000.
8. Amitabha Bagchi, "Efficient Strategies for Topics in Internet Algorithmics," Johns Hopkins Univ., Oct. 2002.
9. Amitabh Chaudhary, "Applied Spatial Data Structures for Large Data Sets," Johns Hopkins Univ., Oct. 2002.
10. Breno De Medeiros, "New Cryptographic Primitives with Applications to Information Privacy and Corporate Confidentiality," Johns Hopkins Univ., May 2004 (co-advised with Giuseppe Ateniese).
11. "Jeremy" Yu Meng, "Confluent Graph Drawing," UC-Irvine, June 2006.

12. Jonathan Zheng Sun, "Algorithms for Hierarchical Structures, with Applications to Security and Geometry," UC-Irvine, Aug. 2006.
13. Nodari Sitchinava, "Parallel External Memory Model—A Parallel Model for Multi-core Architectures," UC-Irvine, Sep. 2009.
14. Darren Strash, "Algorithms for Sparse Geometric Graphs and Social Networks," UC-Irvine, May 2011 (co-advised with with David Eppstein).
15. Lowell Trott, "Geometric Algorithms for Social Network Analysis," UC-Irvine, May 2013.
16. Joseph Simons, "New Dynamics in Geometric Data Structures," UC-Irvine, May 2014.
17. Pawel Pszona, "Practical Algorithms for Sparse Graphs," UC-Irvine, May 2014.
18. William E. Devanny, "An Assortment of Sorts: Three Modern Variations on the Classic Sorting Problem," UC-Irvine, July 2017 (co-advised with David Eppstein).
19. Siddharth Gupta, "Topological Algorithms for Geographic and Geometric Graphs," UC-Irvine, Aug. 2018 (co-advised with with David Eppstein).
20. Timothy Johnson, "Graph Drawing Representations and Metrics with Applications," UC-Irvine, Aug. 2018.
21. Juan Besa, "Optimization Problems in Directed Graph Visualization," UC-Irvine, Aug. 2019.
22. Nil Mamano Grande, "New Applications of the Nearest-Neighbor Chain Algorithm," UC-Irvine, Sep. 2019 (co-advised with David Eppstein).
23. Pedro Matias, "Exact Learning of Sequences from Queries and Trackers," UC-Irvine, May 2021
24. Martha Osegueda, "Constructing, Counting and Matching Combinatorial and Geometric Shapes," UC-Irvine, May 2022

Ph.D. Committee Service:

John Augustine	UC-Irvine	Advancement to candidacy, September 2003
Nikos Triandopoulos	Brown U.	Thesis prelim., February 2004
Einar Mykletun	UC-Irvine	Advancement to candidacy, March 2004
Kartic Subr	UC-Irvine	Advancement to candidacy, September 2004
S. Joshua Swamidass	UC-Irvine	Advancement to candidacy, April 2005
Jeong Hyun Yi	UC-Irvine	Thesis defense, August, 2005
Nodari Sitchinava	UC-Irvine	Advancement to candidacy, chair, December 2005
John Augustine	UC-Irvine	Thesis defense, July 2006
Maithili Narasimha	UC-Irvine	Thesis defense, August, 2006
Josiah Carlson	UC-Irvine	Advancement to candidacy, August 2006
Xiaomin Liu	UC-Irvine	Advancement to candidacy, September 2006
Gabor Madl	UC-Irvine	Advancement to candidacy, September 2006
Nikos Triandopoulos	Brown U.	Thesis defense, September 2006
Rabia Nuray-Turan	UC-Irvine	Advancement to candidacy, May 2007
S. Joshua Swamidass	UC-Irvine	Thesis defense, June 2007
Michael Sirivianos	UC-Irvine	Advancement to candidacy, June 2007
Kevin Wortman	UC-Irvine	Advancement to candidacy, August 2007
Di Ma	UC-Irvine	Advancement to candidacy, December 2007
Josiah Carlson	UC-Irvine	Thesis defense, December 2007
Michael Nelson	UC-Irvine	Advancement to candidacy, chair, March 2008
Minas Gjoka	UC-Irvine	Advancement to candidacy, June 2008
Sara Javanmardi	UC-Irvine	Advancement to candidacy, June 2008
Ali Zandi	UC-Irvine	Advancement to candidacy, September 2008

Jihye Kim	UC-Irvine	Thesis defense, September 2008
Darren Strash	UC-Irvine	Advancement to candidacy, December 2008
Kevin Wortman	UC-Irvine	Topic defense, January 2009
Nodari Sitchinava	UC-Irvine	Topic defense, chair, June 2009
Fabio Soldo	UC-Irvine	Advancement to candidacy, July 2009
Emil De Cristofaro	UC-Irvine	Advancement to candidacy, July 2009
Di Ma	UC-Irvine	Thesis defense, August 2009
Yanbin Lu	UC-Irvine	Advancement to candidacy, December 2009
Anh Le	UC-Irvine	Advancement to candidacy, April 2010
Lowell Trott	UC-Irvine	Advancement to candidacy, June 2010
Xiaomin Liu	UC-Irvine	Thesis defense, August 2010
Josh Olsen	UC-Irvine	Advancement to candidacy, September 2010
Yasser Altowim	UC-Irvine	Advancement to candidacy, December 2010
Angela Wong	UC-Irvine	Advancement to candidacy, May 2011
Joshua Hill	UC-Irvine	Advancement to candidacy, September 2011
Alex Abatzoglou	UC-Irvine	Advancement to candidacy, September 2011
Michael Wolfe	UC-Irvine	Masters Thesis defense, October 2011
Olya Ohrimenko	Brown Univ.	PhD Thesis proposal, October 2011
Yanbin Lu	UC-Irvine	PhD Thesis defense, November 2011
Chun Meng	UC-Irvine	Advancement to candidacy, December 2011
Abinesh Ramakrishnan	UC-Irvine	Advancement to candidacy, March 2012
Pegah Sattari	UC-Irvine	PhD Thesis defense, April 2012
Michael Bannister	UC-Irvine	PhD Thesis defense, May 2015
Yingyi Bu	UC-Irvine	PhD Thesis defense, August 2015
Jenny Lam	UC-Irvine	PhD Thesis defense, November 2015
Timothy Johnson	UC-Irvine	Advancement to candidacy, chair, June 2016
Jiayu Xu	UC-Irvine	Advancement to candidacy, November 2016
Sky Faber	UC-Irvine	PhD Thesis defense, November 2016
Juan Jose Besa Vial	UC-Irvine	Advancement to candidacy, chair, March 2017
William Devanny	UC-Irvine	PhD Thesis defense, co-chair, July 2017
Ingo van Duijn	Aarhus Univ.	PhD Thesis defense, September 2017
Siddharth Gupta	UC-Irvine	Advancement to candidacy, January 2018
Boyang Wei	UC-Irvine	PhD Thesis defense, August 2018
Timothy Johnson	UC-Irvine	PhD Thesis defense, chair, August 2018
Siddharth Gupta	UC-Irvine	PhD Thesis defense, August 2018
Pedro Matias	UC-Irvine	Advancement to candidacy, chair, May 2019
Juan Jose Besa Vial	UC-Irvine	PhD Thesis defense, chair, August 2019
Sameera Chayyur	UC-Irvine	Advancement to candidacy, September 2019
Nil Mamano Grande	UC-Irvine	PhD Thesis defense, co-chair, September 2019
Yihan Sun	CMU	PhD Thesis defense, October 2019
Martha Osegueda	UC-Irvine	Advancement to candidacy, chair, June 2020
Tatiana Bradley	UC-Irvine	PhD Thesis defense, December 2020
Julius Ceasar Aguma	UC-Irvine	Advancement to candidacy, December 2020
Ramtin Afshar	UC-Irvine	Advancement to candidacy, chair, March 2021
Pedro Matias	UC-Irvine	PhD Thesis defense, chair, May 2021
Elham Havvaei	UC-Irvine	PhD Thesis defense, May 2021
Daniel Frishberg	UC-Irvine	Advancement to candidacy, May 2021
Hadi Khodabandeh	UC-Irvine	Advancement to candidacy, July 2021

Sameera Ghayyur	UC-Irvine	PhD topic defense, February 2022
Rohith Gangam	UC-Irvine	Advancement to candidacy, May 2022
Martha Osegueda	UC-Irvine	PhD Thesis defense, chair, May 2022
Yanqi Gu	UC-Irvine	Advancement to candidacy, June 2022
Sameera Ghayyur	UC-Irvine	PhD Thesis defense, August 2022
Rasmus K. Petersen	Aarhus Univ.	PhD Thesis defense, Sept. 2022
Zihan Yu	UC-Irvine	Advancement to candidacy, Nov. 2022

University Service:

Ph.D. Requirements Committee, Dept. of Computer Science, chair: 1987–89
Graduate Admissions Committee, Dept. of Computer Science, 1991–1993 (chair: 1992)
Faculty Recruiting Committee, Dept. of Computer Science, 1993,95,96 (chair: 1996)
Steering Committee, Whiting School of Engineering, 1990–93 (chair, 1993)
Johns Hopkins Homewood Academic Computing Oversight Committee, 1990–93
Curriculum Committee, Whiting School of Engineering, 1994–96
Strategic Planning Committee, Whiting School of Engineering, 1999–00
Graduate Policy Committee, UCI Dept. of Information & Computer Science (ICS), 2001–02
Faculty Search Committee in Cryptography, UCI Dept. of ICS, 2001–03
School of Info. and Computer Science Executive Committee, 2002–04
UCI Committee on Educational Policy (CEP), 2002–03, 2004–06
UCI Change of Major Criteria Committee, 2002–03
UCI CEP Policy Subcommittee, 2002–2003
Distinguished Faculty Search Committee, Bren School of ICS, 2004–11 (chair, 2007–08)
Equity Advisor, Bren School of ICS, 2005–09
Dean's Advisory Council, Bren School of ICS, 2007–13
Associate Dean for Faculty Development, Bren School of ICS, 2006–12
Chair, Department of Computer Science, Bren School of ICS, 2012–13
Master of Computer Science Development Committee, Bren School of ICS, 2013–16
Stragic Planning Committee, Dept. of Computer Science, Bren School of ICS, 2015–16
Master of Computer Science Steering/Admissions Comm., Bren School of ICS, 2016–22
Executive Committee, Bren School of ICS, 2017–18
UC-Irvine Senate Committee on Scholarly Honors & Awards, 2017–20
UC-Irvine Special Research Program Review Committee for CalIT2, 2018–19

Courses Taught and Developed:

Advanced Parallel Computing (developed and taught at Johns Hopkins)
Cyber-Puzzlers (designed and taught at UCI)
Computer Literacy (taught at Purdue, developed at Johns Hopkins)
Computer Programming for Scientists and Engineers (taught at Purdue)
Computer Security Algorithms (developed and taught at UCI)
Computational Models (revised and taught at Johns Hopkins)
Computational Geometry (revised and taught at Johns Hopkins and UCI)
Compiler Theory and Design (revised and taught at Johns Hopkins)
Computer Graphics (taught at Johns Hopkins)
Cyber-Fraud Detection and Prevention (designed and taught at UCI)
Data Structures (revised and taught at Johns Hopkins and UCI)
Graph Algorithms (revised and taught at UCI)
Formal Languages and Automata Theory (revised and taught at UCI)
Fundamentals of Algorithms with Applications (revised and taught at UCI)

Introduction to Algorithms (developed and taught at Johns Hopkins and UCI)
Internet Algorithmics (developed and taught at Johns Hopkins, Brown, and UCI)
Design and Analysis of Algorithms (revised and taught at Johns Hopkins and UCI)
Parallel Algorithms (developed and taught at Johns Hopkins and Univ. of Illinois)
Project in Algorithms and Data Structures (revised and taught at UCI)
Text Processing and Pattern Matching (developed and taught at UCI)

Consulting:

APAC Security, Inc., 2005
Algomagic Technologies, Inc., 2000–2005
Army Research Laboratory, Fort Belvior, 1995
AT&T, 1998
Battelle Research Triangle, Columbus Division, 1996
Brown University, 2000–2007
3M, 2015
Purdue University, 2002
The National Science Foundation, 1990–2016
Univ. of Miami, 1999
Walt Disney Animation Studios, 2009
Technical expert and expert witness, retained for IP litigations, 2012–

GRANTS AND CONTRACTS

1. PI, "Research Initiation Award: Parallel and Sequential Computational Geometry," National Science Foundation (NSF Grant CCR-8810568), $32,914, 1988–90.
2. co-PI, "Paradigms for Parallel Algorithm Design," NSF and DARPA (as NSF Grant CCR-8908092), $523,837, 1989–93 (with S.R. Kosaraju (PI), S. Kasif, and G. Sullivan).
3. PI, "Parallel Computation and Computational Geometry," NSF (Grant CCR-9003299), $67,436, 1990–93.
4. co-PI, "A Facility for Experimental Validation," NSF (Grant CDA-9015667), $1,476,147, 1991–96 (with G. Masson (PI), J. Johnstone, S. Kasif, S.R. Kosaraju, S. Salzberg, S. Smith, G. Sullivan, L. Wolff, and A. Zwarico).
5. PI, "Parallel Network Algorithms for Cell Suppression," The Bureau of the Census (JSA 91-23), $14,998 1991–92.
6. PI, "A Geometric Framework for the Exploration & Analysis of Astrophysical Data," NSF (Grant IRI-9116843), $535,553, 1991–96 (with S. Salzberg and H. Ford (from Physics and Astronomy Dept.)).
7. PI, "Research Experiences for Undergraduates supplement to IRI-9116843," NSF, $4,000, 1993–94 (with S. Salzberg and H. Ford).
8. PI, "Constructing, Maintaining, and Searching Geometric Structures," NSF (Grant CCR-9300079), $134,976, 1993–96.
9. co-PI, "Robust and Applicable Geometric Computing," Army Research Office (ARO MURI Grant DAAH04-96-1-0013), $4,500,000, 1996–2000 (with F. Preparata (PI, Brown U.), R. Tamassia (Brown U.), S. Rao Kosaraju, J. Vitter (Duke U.), and P. Agarwal (Duke U.)). Subaward size: $1,466,640.
10. PI, "Application-Motivated Geometric Algorithm Design," NSF (Grant CCR-9625289), $107,389, 1996-98.
11. co-PI, "vBNS Connectivity for the Johns Hopkins University," NSF, $350,000, 1997–99 (with T.O. Poehler (PI), D.J. Binko, J.G. Neal, and A.S. Szalay).

12. co-PI, “Product Donation, Technology for Education Program,” Intel Corporation, $480,071, 1997–2001 (with T.O. Poehler (PI), J.H. Anderson, A.S. Szalay, and M. Robbins).
13. co-PI, “A Networked Computing Environment for the Manipulation & Visualization of Geometric Data” (Research Infrastructure), NSF, $1,638,785, 1997–2003 (with L.B. Wolff (PI), Y. Amir, S.R. Kosaraju, S. Kumar, R. Tamassia (Brown U.), R.H. Taylor, and D. Yarowsky).
14. PI, “Geometric Algorithm Design and Implementation,” NSF, Grant CCR-9732300, $224,982, 1998–2002.
15. PI, “Certification Management Infrastructure – Certificate Revocation,” $52,023, 1998, NSA LUCITE grant.
16. PI, “Software Engineering Data Loading, Analysis, and Reporting,” $41,614, 1998, NSA LUCITE grant.
17. PI, “Establishing a LUCITE Collaboration Environment,” $10,018, 1998, NSA LUCITE grant.
18. PI, “In Support of a Secure Multilingual Collabortive Computing Environment,” $51,471, 1999-2000, NSA LUCITE grant.
19. PI, “Accessing Large Distributed Archives in Astronomy and Particle Physics,” $199,981. subcontract to UCI from Johns Hopkins Univ. on NSF Grant PHY-9980044 (total budget, $2,500,000), 1999–2004.
20. PI, “Efficient and Scalable Infrastructure Support for Dynamic Coalitions,” $1,495,000, DARPA Grant F30602-00-2-0509, 2000-2003 (with Robert Cohen and Roberto Tamassia), including $227,893 subaward to UCI (with Gene Tsudik).
21. PI, “Graph Visualization and Geometric Algorithm Design,” $400,000, NSF Grant CCR-0098068, 2001-2004 (with Roberto Tamssia).
22. PI, “Collaborative Research: Teaching Data Structures to the Millennium Generation,” $125,00, NSF Grant DUE-0231467, 2003–2005.
23. PI, “Collaborative Research: An Algorithmic Approach to Cyber-Security,” $100,000, NSF Grant CCR-0311720, 2003–2006.
24. PI, “The OptIPuter,” $900,000, subcontract from UCSD on NSF ITR grant CCR-0225642 (total budget, $13.5 million), 2002–2007 (with Padhraic Smyth and Kane Kim).
25. PI, “ITR: Algorithms for the Technology of Trust,” $300,000, NSF Grant CCR-0312760, 2003–2009.
26. co-PI, “SDCI Data New: Trust Management for Open Collaborative Information Repositories: The CalSWIM Cyberinfrastructure,” NSF grant OCI-0724806, $1,103,590, 2007–2012.
27. co-PI, “Support for Machine Learning Techniques for Cyber-Fraud Detection,” Experian Corporation, $200,000 gift, 2008.
28. PI, “IPS: Collaborative Research: Privacy Management, Measurement, and Visualization in Distributed Environments,” NSF Grant IIS-0713046, $224,851, 2007–2009.
29. PI, “Collaborative Research: Algorithms for Graphs on Surfaces,” $400,000, NSF Grant CCR-0830403, 2008–2011.
30. PI, “ROA Supplement: IPS: Collaborative Research: Privacy Management, Measurement, and Visualization in Distributed Environments,” NSF Grant IIS-0847968, $25,000, 2008–2009.
31. co-investigator, “Scalable Methods for the Analysis of Network-Based Data,” Office of Naval Research: Multidisciplinary University Research Initiative (MURI) Award, number N00014-08-1-1015, $529,152, 2008–2014.
32. PI, “EAGER: Usable Location Privacy for Mobile Devices,” NSF Grant 0953071, $300,000, 2009–2011.

33. PI, "TC:Large:Collaborative Research: Towards Trustworthy Interactions in the Cloud," NSF Grant 1011840, $500,000, 2010-2015.
34. PI, "TWC: Medium: Collaborative: Privacy-Preserving Distributed Storage and Computation," NSF Grant 1228639, $390,738, 2012-2018.
35. PI, "Support for Research on Geometric Motion Planning," 3M Corporation, $40,000 gift, 2014.
36. PI, "A4V: Automated Analysis of Algorithm Attack Vulnerabilities," subcontract 10036982-UCI from University of Utah for DARPA agreement no. AFRL FA8750-15-2-0092, $980,000, 2015–2019.
37. PI, "TWC: Small: Collaborative: Practical Security Protocols via Advanced Data Structures," NSF Grant 1526631, $166,638, 2015–2018.
38. PI, "NSF-BSF: AF: Small: Geometric Realizations and Evolving Data," NSF Grant 1815073, $474,392, 2018–2022.
39. PI, "Collaborative Research: AF: Medium: Algorithms for Geometric Graphs," NSF Grant 2212129, $799,800, 2022–2026.

SELECTED INVITED TALKS (RECENT YEARS ONLY)

- "Probabilistic Packet Marking for Large-Scale IP Traceback," Purdue Univ., 2003
- "Algorithms for Data Authentication," Harvey Mudd College, 2003
- "Efficient Tree-Based Revocation in Groups of Low-State Devices," Univ. of Arizona, 2004
- "Leap-Frog Packet Linking and Diverse Key Distributions for Improved Integrity in Network Broadcasts," Southern California Security and Cryptography Workshop, 2005
- "Is Your Business Privacy Protected?," NEXT Connections, 2005
- "Distributed Peer-to-peer Data Structures," Harvard Univ., 2006
- "Balancing Life with an Academic Research Career," Grace Hopper Conference, 2006
- "Computer Security in the Large," Univ. Texas, San Antonio, 2006
- "Inspirations in Parallelism and Computational Geometry," Brown Univ., 2006
- "Efficiency and Security Issues for Distributed Data Structures," Computer Science Distinguished Lecture Series, Johns Hopkins Univ., 2006
- "Efficiency and Security Issues for Distributed Data Structures," UCLA, 2006
- "Efficiency and Security Issues for Distributed Data Structures," Edison Distinguished Lecturer Series, Univ. of Notre Dame, 2006
- "Efficiency and Security Issues for Distributed Data Structures," Computer Science Distinguished Lecturer Series, Texas A & M Univ., 2006
- "Algorithms for Secure Computing and Searching with Applications to Medical Informatics," Purdue Univ., 2006
- "Blood on the Computer: How Algorithms for Testing Blood Samples can be Used for DNA Sequencing, Wireless Broadcasting, and Network Security," Univ. of Southern California, 2007
- "Blood on the Computer: How Algorithms for Testing Blood Samples can be Used for DNA Sequencing, Wireless Broadcasting, and Network Security," Univ. California, San Diego, 2007
- "Blood on the Computer: How Algorithms for Testing Blood Samples can be Used for DNA Sequencing, Wireless Broadcasting, and Network Security," Univ. Minnesota, 2007
- "Blood on the Database: How Algorithms for Testing Blood Samples can be Used for Database Integrity," Invited Keynote, 21st Annual IFIP WG 11.3 Working Conference on Data and Applications Security (DBSec), 2007

- “Space-Efficient Straggler Identification,” ALCOM Seminar, Univ. of Aarhus, 2007
- “Blood on the Computer: How Algorithms for Testing Blood Samples can be used in Modern Applications,” ALCOM Seminar, Univ. of Aarhus, 2007
- “Studying Road Networks Through an Algorithmic Lens,” ALCOM Seminar, Univ. of Aarhus, 2008
- “Studying Geometric Graph Properties of Road Networks Through an Algorithmic Lens,” International Workshop on Computing: from Theory to Practice, 2009
- “Randomized Shellsort: A Simple Oblivious Sorting Algorithm,” Distinguished Lecture Series, Department of Computer Science, Brown University, 2009
- “Simulating Parallel Algorithms in the MapReduce Framework with Applications to Parallel Computational Geometry,” MASSIVE 2010
- “Data Cloning Attacks for Nearest-Neighbor Searching based on Retroactive Data Structures,” Department of Computer Science, UCSB, 2011
- “Turning Privacy Leaks into Floods: Surreptitious Discovery of Social Network Friendships and Other Sensitve Binary Attribute Vectors,” Department of Computer Science Distinguished Lecturer Series, Univ. of Illinois, Chicago, 2011
- “Turning Privacy Leaks into Floods: Surreptitious Discovery of Social Network Friendships and Other Sensitve Binary Attribute Vectors,” Department of Computer Science, Purdue Univ., 2011
- “Spin-the-bottle Sort and Annealing Sort: Oblivious Sorting via Round-robin Random Comparisons,” Department of Computer Science, Brown Univ., 2012
- “Using Data-Oblivious Algorithms for Private Cloud Storage Access,” Qatar University, 2013
- “Using Data-Oblivious Algorithms for Private Cloud Storage Access,” Department of Computer Science and Engineering Distinguished Speaker Series, University of Buffalo, 2013
- “Force-Directed Graph Drawing Using Social Gravity and Scaling,” invited talk, ICERM Workshop on Stochastic Graph Models, Providence, RI, 2014
- “Invertible Bloom Lookup Tables and Their Applications in Large-Scale Data Analysis,” invited key-note speaker, Algorithms for Big Data, Frankfurt, Germany, 2014
- “Invertible Bloom Lookup Tables and Their Applications in Large-Scale Data Analysis,” Brown University, Providence, RI, 2014
- “Studying Road Networks Through an Algorithmic Lens,” Bold Aspirations Visitor and Lecture, University of Kansas, 2015
- “Learning Character Strings via Mastermind Queries, with Case Studies,” Invited Lecture, Workshop on Pattern Matching, Data Structures and Compression, Bar-Ilan University, Tel Aviv, Israel, 2016
- “Invertible Bloom Lookup Tables and Their Applications in Data Analysis,” University of Hawaii, 2016
- “Invertible Bloom Lookup Tables,” Purdue University, 2016
- “Combinatorial Pair Testing: Distinguishing Workers from Slackers,” Calvin Univ., 2016
- “Invertible Bloom Lookup Tables,” University of California, Riverside, 2016
- “2-3 Cuckoo Filters for Faster Triangle Listing and Set Intersection,” Technion, Israel Institute of Technology, Haifa, Israel, 2017
- “2-3 Cuckoo Filters for Faster Triangle Listing and Set Intersection,” University of Arizona, 2017
- “Parallel Computational Geometry,” First Hawaii Workshop on Parallel Algorithms and Data Structures, University of Hawaii, 2017

- "Fighting Gerrymandering with Algorithmic Fairness," Calvin University, 2019
- "Fighting Gerrymandering with Algorithmic Fairness," Carnegie Mellon University, 2019
- "Sorting Evolving Data in Parallel," Second Hawaii Workshop on Parallel Algorithms and Data Structures, University of Hawaii, 2019
- "Dealing with Big Data via External Memory Algorithms and Data Structures," Aarhus University, Denmark, 2021
- "Dealing with Big Data via External Memory Algorithms and Data Structures," Royal Danish Academy of Sciences and Letters, 2021